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PROTOTYPE MULTITONE DETECTOR FOR SCOPE CONTROL.(U)
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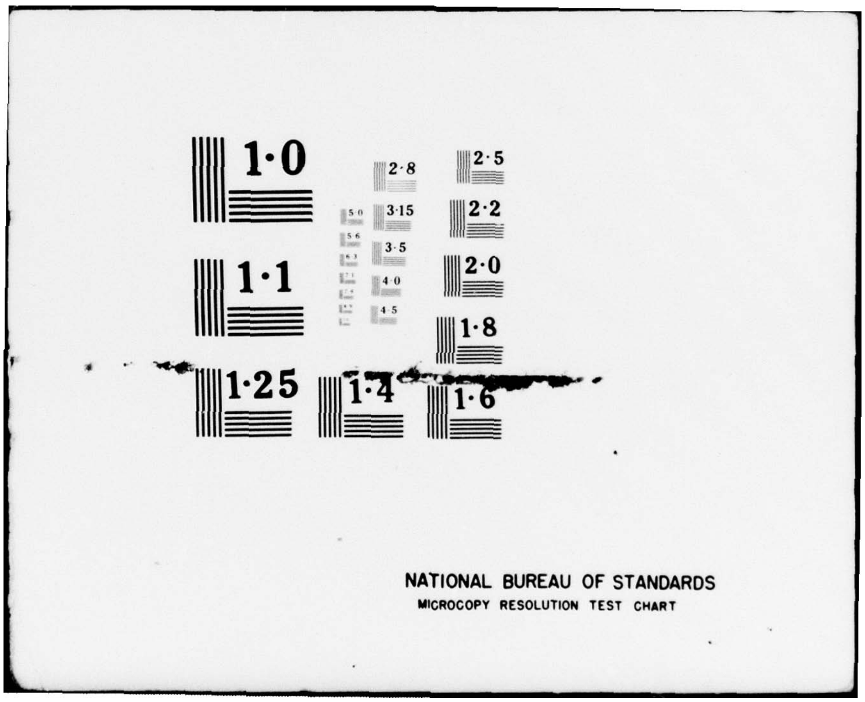
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1842 EEG/EETD TR77-20

AFCS TECHNICAL REPORT

PROTOTYPE MULTITONE DETECTOR FOR SCOPE CONTROL

DIGITAL AND NARROWBAND SYSTEMS BRANCH
1842 ELECTRONICS ENGINEERING GROUP (AFCS)
RICHARDS-GEBAUR AIR FORCE BASE, MISSOURI

23 SEPTEMBER 1977

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
(14) 1842 EEG/EETD-TR77-20

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER
N/A

4. TITLE (and Subtitle)
(6) Prototype Multitone Detector for Scope Control

5. TYPE OF REPORT & PERIOD COVERED
N/A

6. PERFORMING ORG. REPORT NUMBER
N/A

7. AUTHOR(s)
(10)
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8. CONTRACT OR GRANT NUMBER(s)
N/A

9. PERFORMING ORGANIZATION NAME AND ADDRESS
1842 EEG/EETD
Richards-Gebaur AFB, MO 64030

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
(12) 22p.

11. CONTROLLING OFFICE NAME AND ADDRESS
1842 EEG/EETD
Richards-Gebaur AFB, MO 64030

12. REPORT DATE
(11) 23 Sep[redacted]977

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
(9) Technical rept.;
1842 EEG/EEISD
Richards-Gebaur AFB, MO 64030

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release. Distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

N/A

18. SUPPLEMENTARY NOTES

N/A

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tone detection, active filters, circuit design.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A circuit board to replace the existing wideband detector cards and solve the problem of switchboard dropouts at the Clark AB Scope Control Aeronautical station was designed and constructed by 1842 EEG/EETDN. This report describes the circuit design, laboratory tests, and field test results.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

APPROVAL PAGE

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1. INTRODUCTION. This report outlines the development of a prototype multitone circuit board designed to replace the existing wideband detector cards in the Clark AB Scope Control Aeronautical station.

2. BACKGROUND.

2.1 THE PROBLEM. Scope Control is a worldwide network of HF/SSB aeronautical stations. Andrews AFB is designated as the master net control station (MNCS) and is connected to several other Scope Control stations by dedicated S-3 conditioned lines. The Scope Control system uses in-band FSK and DTMF signals to remotely control and condition local and remote equipments. To establish a remote data link, the MNCS operator may be required to dial 20 digits or more. If, at any point in the dialing sequence, the tone detection hold devices release because of level changes, circuit noise, etc., the dialing sequence must be restarted. It is this problem with noise, level changes, and attenuation on the 210F line circuit between Andrews AFB and Clark AB, PI that has caused the wideband detectors at Clark AB to unlock and drop the circuit.

2.2 THE SOLUTION. The solution to the problem of dropouts was perceived to be one of making the wideband detector less sensitive to noise and level changes. Two methods of doing this were originally proposed. The first proposal was to add narrowband active filters to the input of the existing wideband detector card. These filters would pass only the control tone frequencies and would reject any out-of-band noise and interference which might cause a dropout. Since these filters could not easily be located external to the existing wideband detector cards, it was decided that the filters would be included as an integral part of the wideband detector printed circuit boards. This proposal was later rejected for two reasons. First, to achieve the narrow bandwidths required, over 50 passive components were needed. This presented layout problems as space on the circuit board was limited. Second, the narrowband filters required several operational amplifiers which required both positive and negative supply voltages. While work on the

narrowband filters was proceeding, a second proposal was formed. This proposal called for a complete redesign of the wideband detector and for incorporating two phase locked loop (PLL) tone detectors. These PLL tone detectors would detect the presence of the 2847 Hz and 3135 Hz FSK control tones and offer some degree of noise immunity. This design was later expanded when it was realized that three tone detectors were required to insure lock-up in all modes of operation. In studying the operation of the new detector card, it was discovered that the PLLs would become unlocked when a high level signal was mixed with the input control tones, even though this signal was not of the same frequency or a subharmonic of the control tone. To solve this problem, a bandpass filter with a passband wide enough to pass all the control tones was added ahead of the PLLs. This filter seemed to offer the degree of interference attenuation desired. After extensive testing at the Prototype Test Facility, one more PLL type detector was constructed, identical to the first, and the two cards were field tested at the McClellan AFB Aeronautical Station. As a result of the McClellan Test, several features of the new cards, both desirable and undesirable, were discovered. The detectors functioned normally on an interstation line from Andrews AFB with control tones attenuated to -28 dBm, and the card continued to function with an out-of-band noise input of up to 10 dB higher than the control tones. However, the detector malfunctioned during data transmission when the data was transmitted at a level greater than its normal level of -6 dBm, or when the locally generated 3160 Hz control tone was lower than its normal level of -26 dBm. Also, the detector would lock for approximately two seconds after initial insertion into the SW-3600 switchboard. This was due to an inherent characteristic of the PLLs where they present a ground at their output for a short time after power is applied. This was an undesirable characteristic of the card because when several of these detectors simultaneously present this ground, the associated lines into the station are unusable. The prototype cards were returned from McClellan and the detector was completely redesigned. A time delay feature was designed which prevented the relay from actuating when the power was

first applied. A comparator circuit was added which would prevent high level data tones from causing an unlock. The passband of the bandpass filter was increased slightly to insure uniform sensitivity to all control tones. Finally, an additional comparator circuit was designed which allowed setting of the drop-out time independent of the pull-in time. The three redesigned prototype cards were installed in the SW-3600 switchboard at Clark AB for what was to be a 30 day test. During the test, the internal oscillators of the PLLs tended to drift off frequency. This was probably due to a temperature rise within the enclosed switchboard and the use of large tolerance, not precision, components. It was also discovered that the detector intermittently became unlocked when the data tones were applied, despite the bandpass filter on the input. This problem was originally identified during the McClellan test, but we were unable to solve it with the improved bandpass filter and comparator circuit. Because of the unfavorable results of the Clark AB test, the use of PLLs was dropped from consideration. While high noise immunity is characteristic of PLLs, it was felt some noise immunity could be sacrificed for the improved stability and lower power consumption demonstrated by other types of devices. Also, by eliminating the PLLs, the accompanying noise associated with their oscillators is eliminated and a potential problem area is avoided.

3. DESIGN.

3.1 CIRCUIT DESIGN. The prototype detector described herein is a pin-for-pin replacement for the existing Collins wideband detector. Operation of the Collins detector is described in Appendix I. The prototype design (Figures 1 and 2) consists of two narrow bandpass filters: one is centered at 2804 Hz and has a bandpass of 120 Hz; the other is centered at 3147 Hz and has a bandpass of 60 Hz. When a signal passes through either of the bandpass filters it is amplified and rectified to produce a DC level input to the comparator circuits. When this DC level is above the threshold set for the respective comparator (U4 or U5), the

output of that comparator goes low causing capacitor C23 to discharge. When C23 discharges to a potential below the preset threshold, comparator U6 goes high, provides base current for Q1, and the relay energizes. When the input signal is removed, comparator U4 (or U5) goes high, capacitor C23 charges to a potential above the preset threshold, comparator U6 goes low, and the relay opens. Pull-in and dropout time is a function of capacitor C23. For the values shown, both pull-in and dropout time is 250 ms. The SCR delay circuit was included to prevent the relays from being actuated when DC power is initially applied to the card.

3.2 LABORATORY TESTS.

3.2.1 PULL-IN AND DROPOUT TIME.

Pull-in and dropout time is independent of input signal level. With the values shown, both pull-in and dropout times are fixed at 250 ms. Should adjustments in pull-in and dropout time be necessary, decreasing or increasing C23 causes a decrease or increase in both pull-in and dropout time. If after changing C23, it is desired to make both pull-in and dropout times equal, this can be done by substituting values for R37.

3.2.2 THRESHOLD ADJUSTMENT.

The threshold level adjustment for each filter leg is adjustable over the range of -27 to -34 dBm.

3.2.3 FILTER PASSBAND.

Bandpass characteristics of the two filters are shown in Figure 3 and 4.

3.2.4 NOISE.

To demonstrate the relative noise immunity of the new cards, both the existing Collins wideband card and the prototype card were adjusted for -30 dBm thresholds with 100 ms dropout time. A General Radio 1390-B random noise generator was connected to the input of each card and the level adjusted until a lock up was achieved. See Figure 1. The Collins card was found to lock at -14 dBm of noise while the prototype card locked at -8 dBm. The prototype card exhibited approximately 6 dB of noise immunity over the existing card.

3.2.5 TEMPERATURE STABILITY. Each of the three prototype cards constructed was placed in an oven and the temperature adjusted to 100°F. Threshold settings were adjusted for -32 dBm at 2847 and 3135 Hz and the low and high filters were centered at 2804 and 3147 Hz, respectively. Voltages at the test points TP1 and TP6 were measured prior to heating, with an input signal of 2804 Hz at -30 dBm and a signal of 3147 Hz at -30 dBm. These measurements are recorded in Table 2. Probes were connected to TP1 and TP6 so that any change in filter gain could be readily determined. After 24 hours in the oven, test point voltages, threshold settings, and the center frequencies of the filters were again measured. Results are tabulated in Table 2 also.

3.3 FIELD TEST RESULTS. Three prototype multitone detector cards were sent to the Clark AB Scope Control Aeronautical station and inserted in the 210F circuit where they remained for 30 days. Throughout the test period, the detector cards were tested for BPF center frequency drift and test point voltage fluctuations. The test results for each card are tabulated in Table 3. No significant variations were recorded over the test period and no circuit outages were attributed to any malfunction of the prototype detectors.

4. CONCLUSIONS AND RECOMMENDATIONS. The new prototype detector is characterized by two major improvements over the existing wideband detector. The prototype detector has approximately 6 dB of additional noise immunity beyond that of the existing detector. Adjustment of pull-in and dropout time is no longer necessary. It is our recommendation that the new multitone detector card be used only at those stations with a confirmed history of circuit outages due to wideband detector dropouts, and then only on the switchboard lines affected.

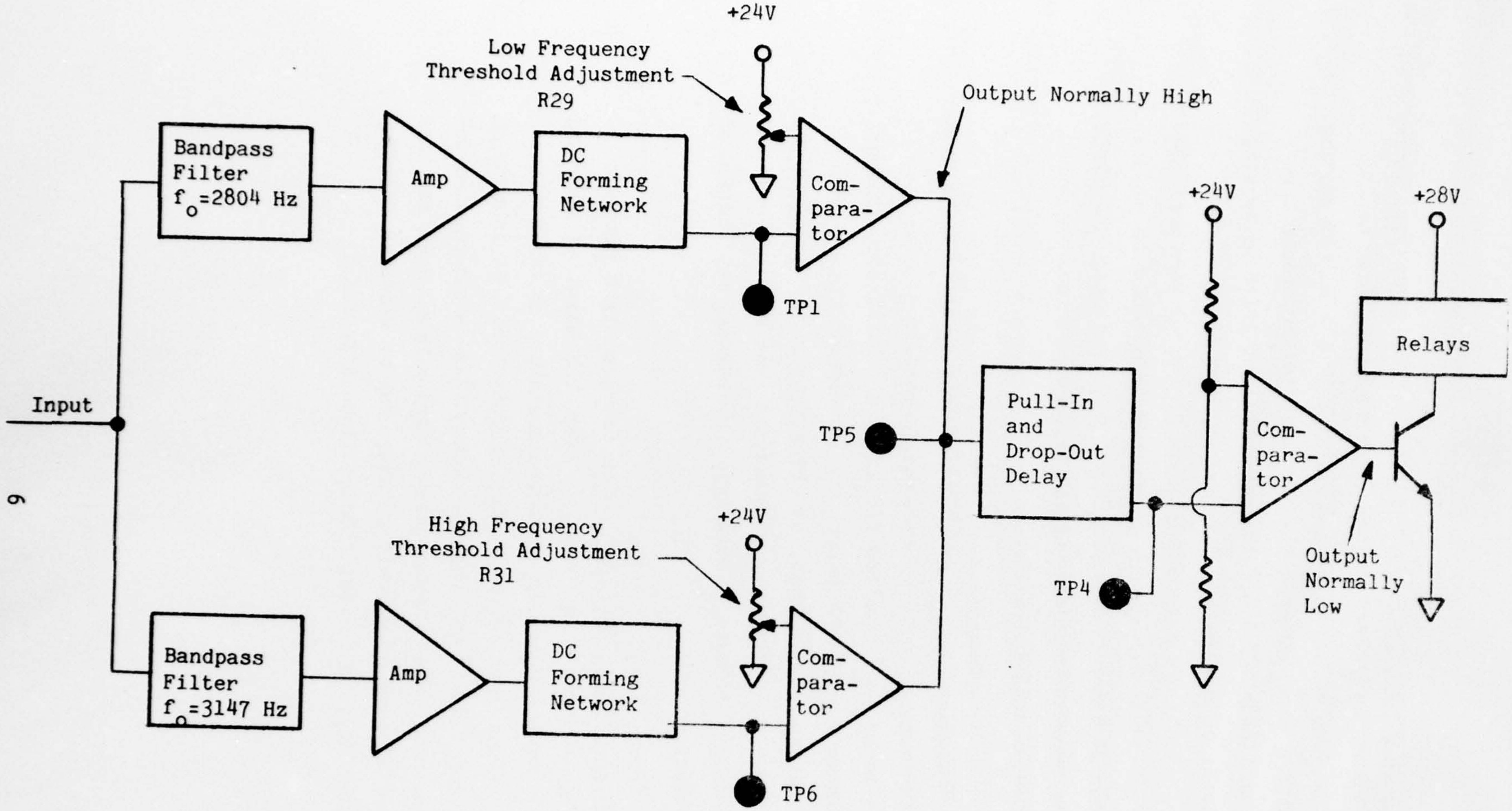
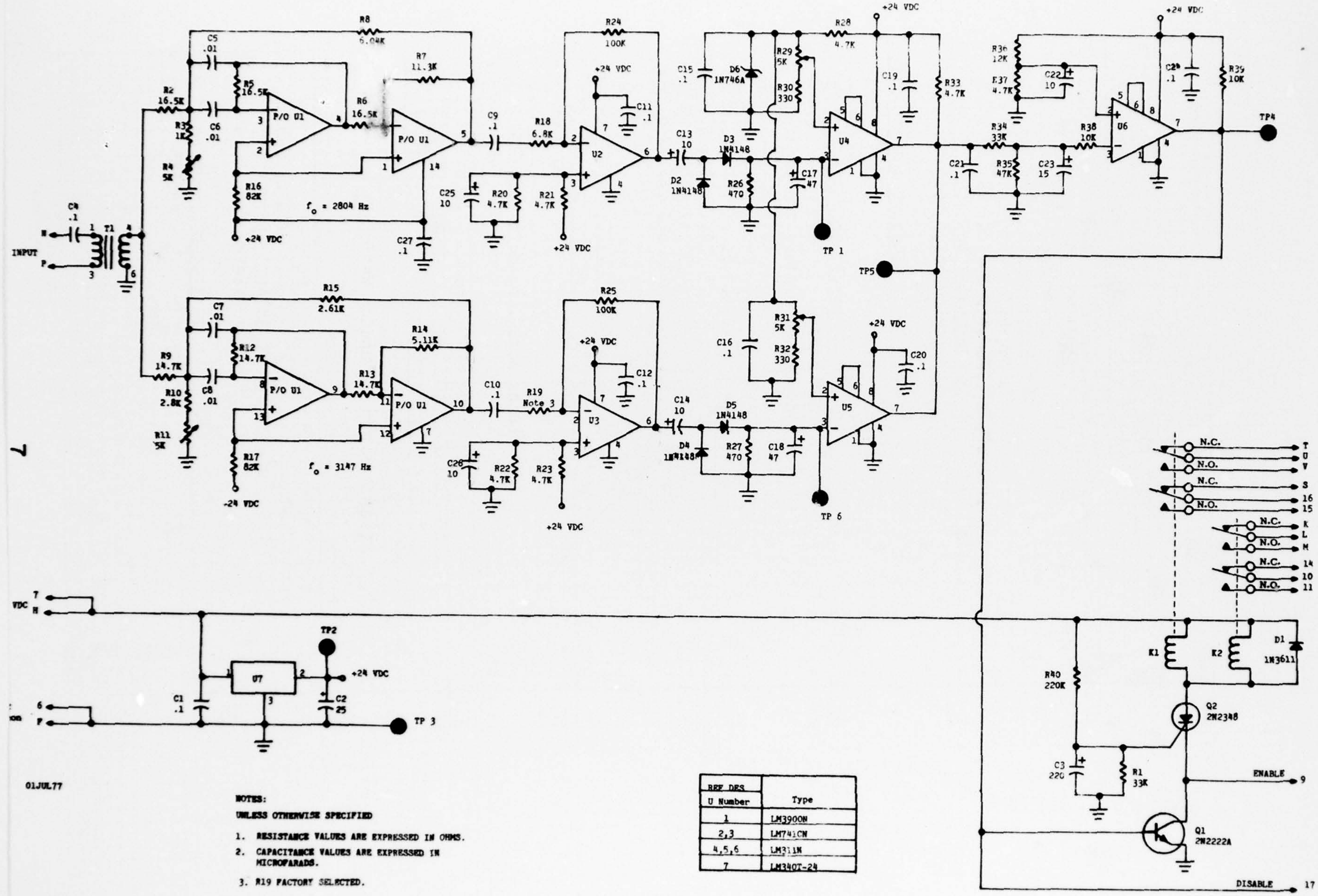


Figure 1

Multitone Detector
Block Diagram



NOTES:

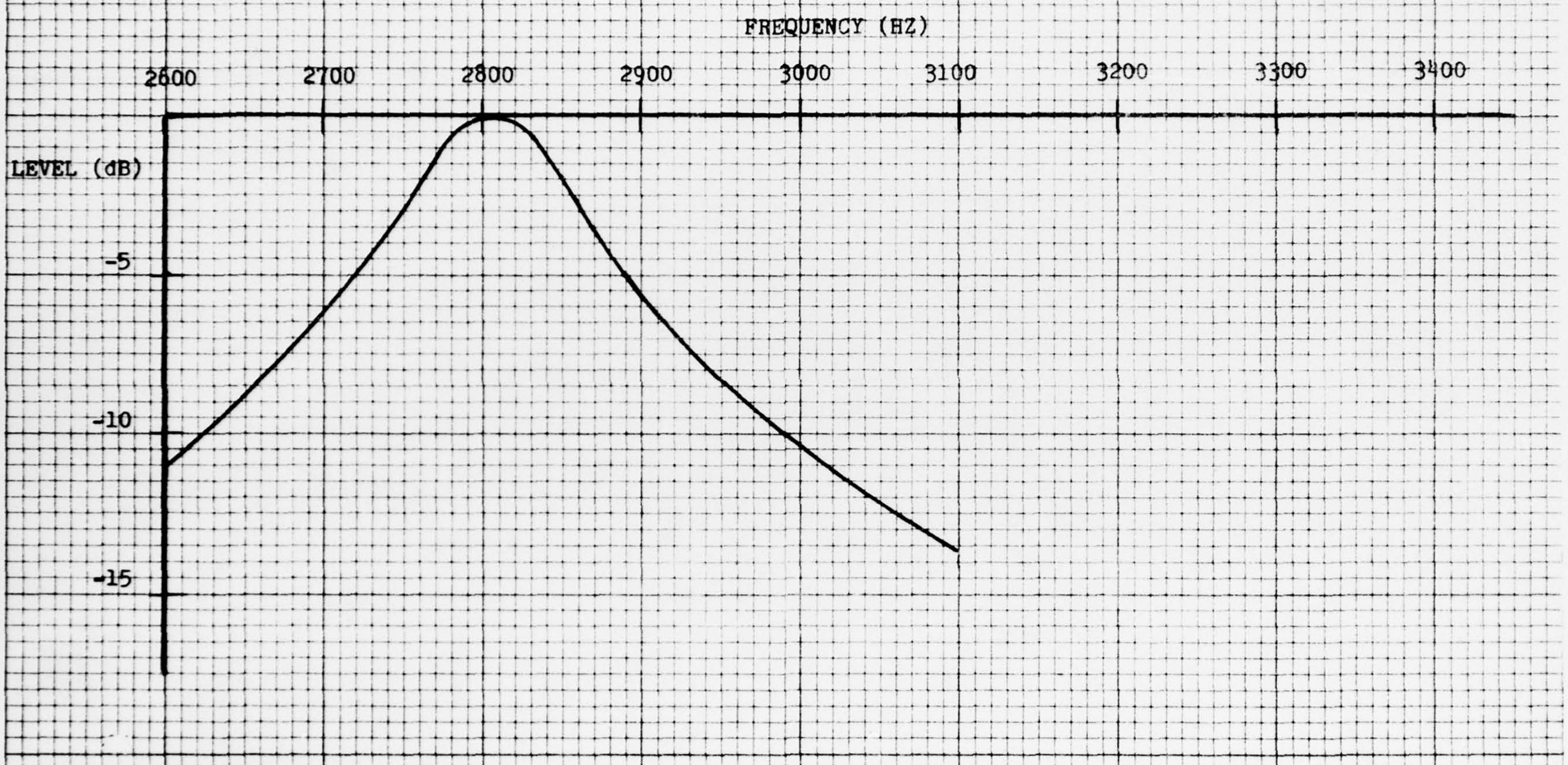
UNLESS OTHERWISE SPECIFIED

1. RESISTANCE VALUES ARE EXPRESSED IN OHMS.
2. CAPACITANCE VALUES ARE EXPRESSED IN MICROFARADS.
3. R19 FACTORY SELECTED.

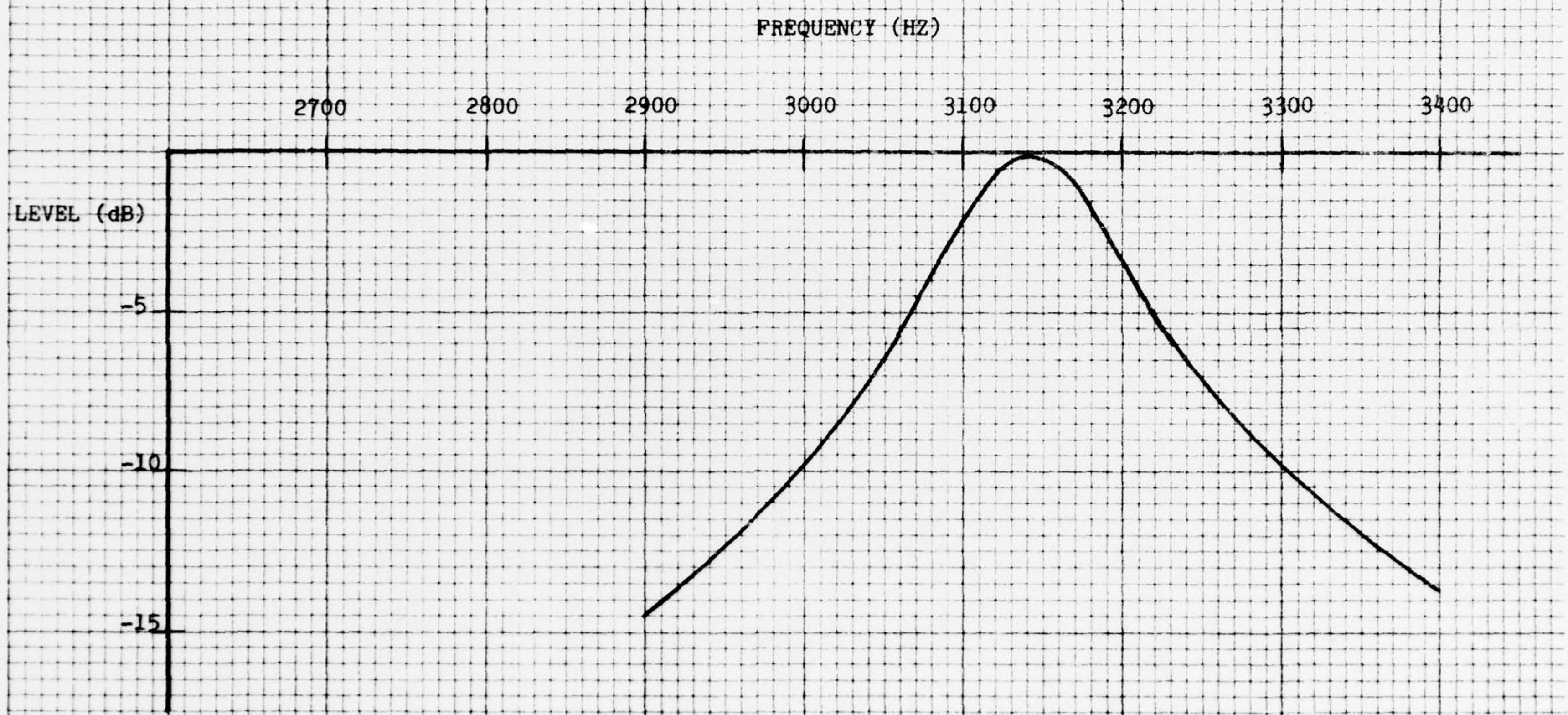
REF DES U Number	Type
1	LM3900N
2,3	LM741CN
4,5,6	LM311N
7	LM340T-24

FIGURE 2

MULTITONE DETECTOR SCHEMATIC DIAGRAM



PROTOTYPE MULTITONE DETECTOR
BANDPASS FILTER FREQUENCY RESPONSE (f_c = 2804 Hz)
FIGURE 3



PROTOTYPE MULTITONE DETECTOR
BANDPASS FILTER FREQUENCY RESPONSE (f_c = 3147 HZ)
FIGURE 4

Table 1

LIST OF COMPONENTS

Capacitors

C1, 4, 9, 10, 11, 12, 15, 16, 19, 20, 21, 24 -.1 mfd, Ceramic
C2 -25 mfd, 50V, Electrolytic
C3 -220 mfd, 25V, Electrolytic
C5, 6, 7, 8 -.01 mfd, Polystyrene
C13, 14, 22, 25, 26 -10 mfd, 25V, Electrolytic
C17, 18 -47 mfd, 25V, Electrolytic
C23 -15 mfd, 10V, Electrolytic

Resistors and Controls

R1, 34 -33K
R2, 5, 6 -16.5K, 1%, 1/10W
R3 -1K
R4, 11 -5K potentiometer, top adjust
R7 -11.3K, 1%, 1/10W
R8 -6.04K, 1%, 1/10W
R9, 12, 13 -14.7K, 1%, 1/10W
R10 -2.8K, 1%, 1/10W
R14 -5.11K, 1%, 1/10W
R15 -2.61K, 1%, 1/10W
R16, 17 -82K
R18 -6.8K
R19 - factory selected, less than 10K
R20, 21, 22, 23, 28, 33, 37 -4.7K
R24, R25 -100K
R26, 27 -470
R29, 31 -5K potentiometer, side adjust
R30, 32 -330
R35 -47K
R36 -12K
R38, 39 -10K
R40 -220K

All resistors $\pm 5\%$, 1/4W unless otherwise stated.

Solid State Devices

D1 - Diode, 1N3611
D2, 3, 4, 5 - Diode, 1N4148
D6 - Zener Diode, 1N746A

Q1 - Transistor, 2N2222A
Q2 - SCR, 2N2348

(Table 1 cont)

U1 - Quad Operational Amplifier, LM3900N
U2, 3 - Operational Amplifier, LM741CN
U4, 5, 6 - Comparator, LM311N
U7 - Voltage Regulator, LM340T-24

Miscellaneous

K1, 2 - Relay, DPDT, 800 ohm, 24 VDC
T1 - Transformer, 10K-to-10K

TABLE 2

Threshold Level, Test Point Voltage, and BPF Center Frequency Before and After Temperature Testing

		Filter	Before	After
Card 1	Threshold	Low High	-32 dBm -32 dBm	-32 dBm -32 dBm
	Voltage	Low (TP1) High (TP6)	2.31V 0.9V	2.28V 0.91V
	Frequency	Low High	2804 Hz 3147 Hz	2802 Hz 3146 Hz
Card 2	Threshold	Low High	-32 dBm -32 dBm	-32 dBm -32 dBm
	Voltage	Low (TP1) High (TP6)	2.08V 1.075V	2.07V 1.095V
	Frequency	Low High	2804 Hz 3146 Hz	2808 Hz 3146 Hz
Card 3	Threshold	Low High	-32 dBm -32 dBm	-31 dBm -32 dBm
	Voltage	Low (TP1) High (TP6)	2.04V 1.15V	2.00V 1.23V
	Frequency	Low High	2802 Hz 3147 Hz	2810 Hz 3154 Hz

Table 3

30 Day Field Test at Clark Aeronautical Station

	Low Frequency Bandpass Filter $f_c = 2804$ Hz		High Frequency Bandpass Filter $f_c = 3147$ Hz	
	f_c Deviation	TP 1 Deviation	f_c Deviation	TP 6 Deviation
Card #1 Switchboard Line 43	±.32%	±2.1%	±.22%	±2.9%
Card #2 MODEM EXIT 1B-Switchboard Line 81	±.18%	±4.6%	±.13%	±4.2%
Card #3 MODEM EXIT 1A-Switchboard Line 80	±.25%	±2.0%	±.22%	±1.6%

APPENDIX 1

COLLINS WIDEBAND DETECTOR

Figure A-1 shows the block diagram of the wideband detector. Relays K1 and K2 are activated by FSK signals present at the input of the wideband detector. To reduce the possibility of relays K1 and K2 being energized on noise signals, several filters have been incorporated to eliminate unwanted frequencies. The audio input to the wideband detector is coupled through transformer T1, developed across threshold resistor R2, and applied to amplifier Q1. The output of amplifier Q1 is applied to the band reject filters, which remove the frequencies immediately below and immediately above the passband. The signal is then amplified by amplifier Q2 and applied through the high pass filter network to emitter follower Q3, removing all frequencies below 2700 Hz. The output of emitter follower Q3, is applied through the low pass filter network to emitter follower Q4, removing all frequencies above 3250 Hz. The output of emitter follower Q4 is any input frequency between 2700 Hz and 3250 Hz (see Figure A-2). The output of emitter follower Q4 is amplified by amplifier Q5 and applied to the detector that converts the audio frequency to a dc signal. This dc voltage is applied to the Schmitt trigger Q6 and Q7, and to the time delay circuit. The Schmitt trigger output switches relay driver Q8 into conduction through relays K1 and K2, energizing the relays. The time delay determines the time between the removal of the input signal and the release of the relays.

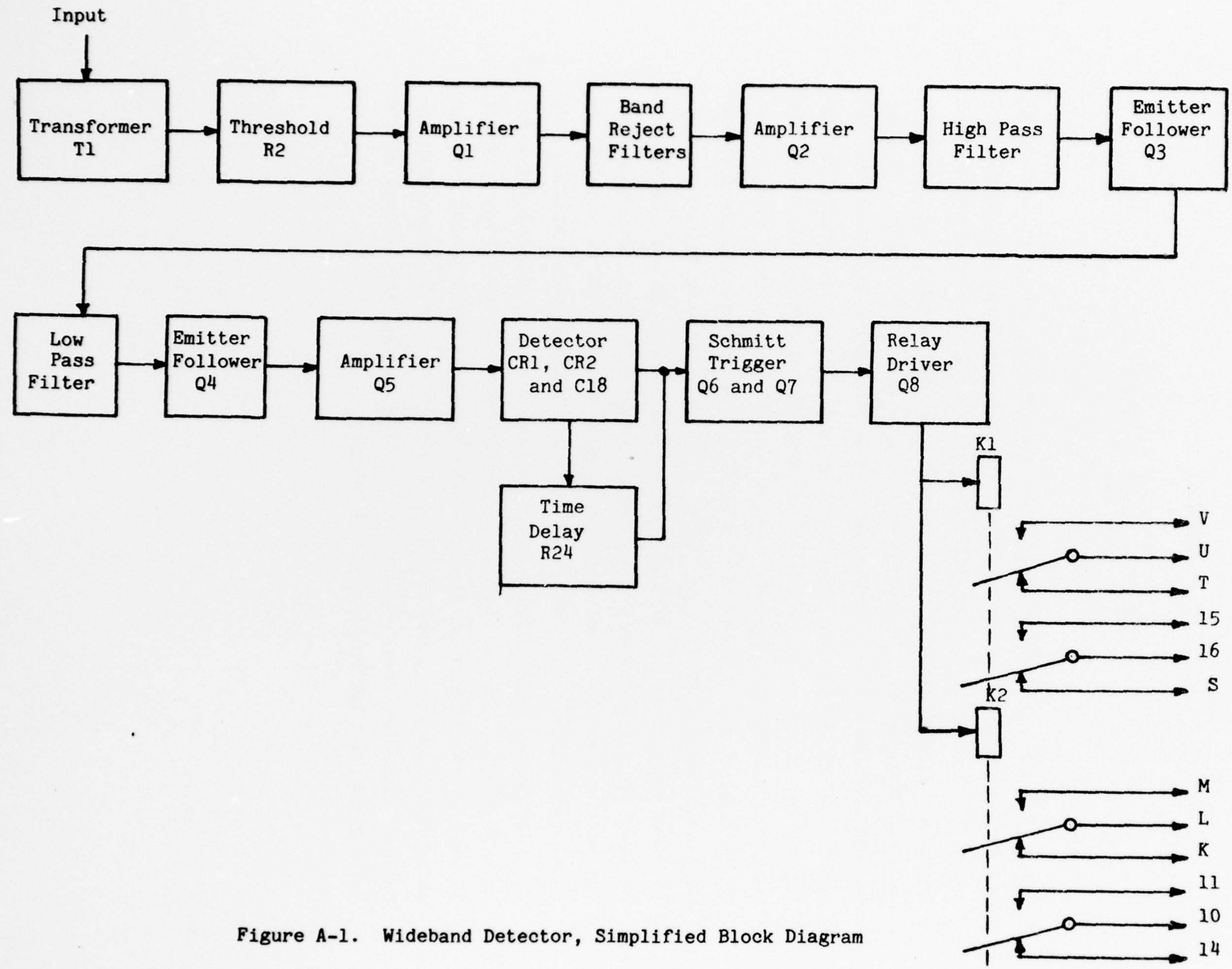
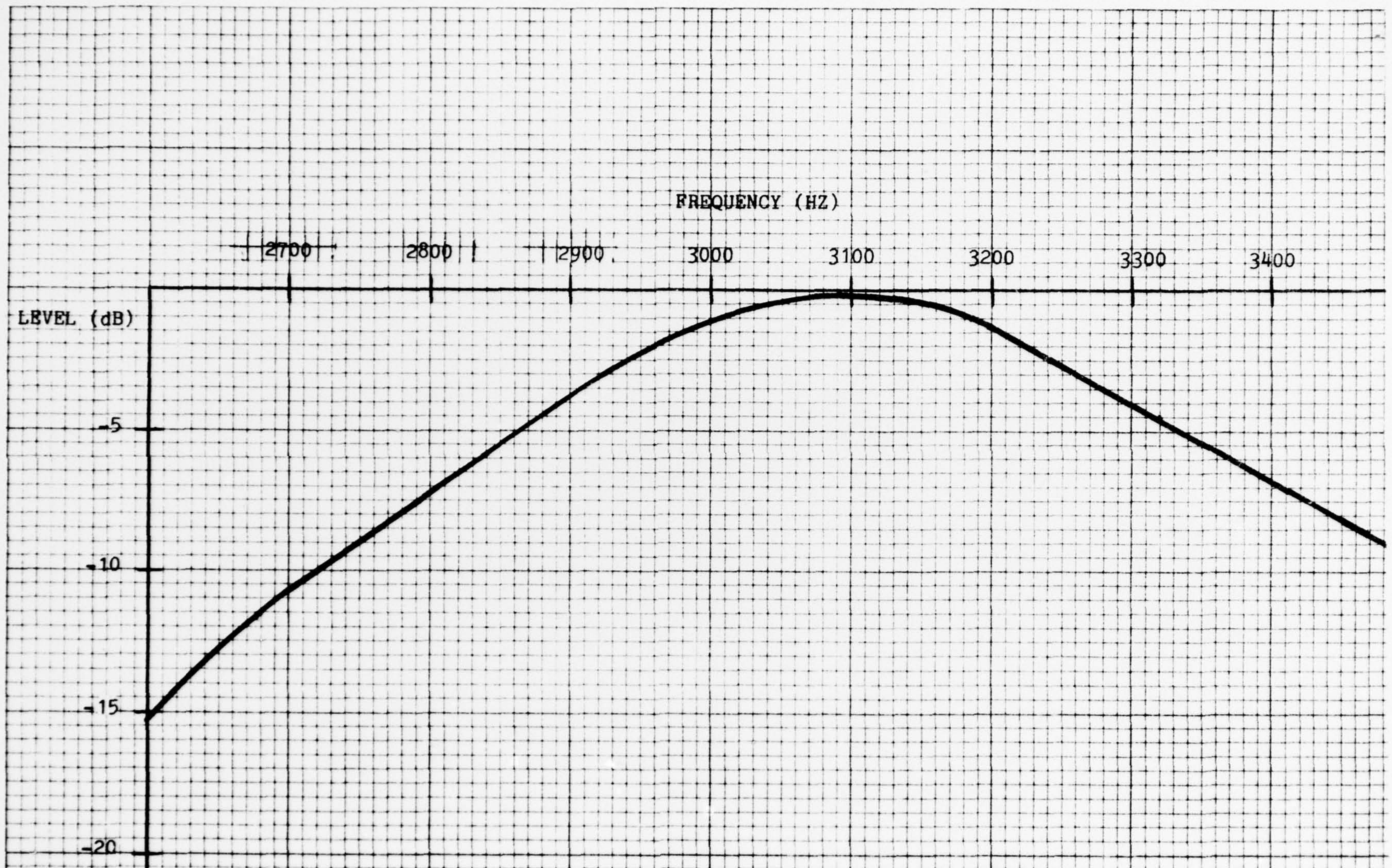


Figure A-1. Wideband Detector, Simplified Block Diagram



COLLINS WIDEBAND DETECTOR
BANDPASS FILTER FREQUENCY RESPONSE

FIGURE A-2

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